CONCEPT TO PRODUCTION WITH A GEN AI DESIGN ASSISTANT: AIDA

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ABSTRACT
In design research there is a deep interest in how designers solve complex problems using design methods and heuristic shortcuts and in particular how this might relate to Machine Language (ML) to simulate the design process. With the introduction of Large Language Model (LLMs) such as Chat GPT we can appreciate how software with the remarkable capability of Generative AI (Gen AI) and generative design can be used to assist designers in the three-dimensional design of their products. In this paper, we will focus on how AI will impact designing in computing, identify what is relevant and suggest a new development opportunity. Our interest is in examining the potential for better and novel software solutions, making them easier to use during the design synthesis process and capable of adjustment throughout the 3D CAD development stage. The specific problem we aim to resolve is how to optimise a designer's time spent from concept to production using Gen AI & 3D CAD software without affecting the quality of design thinking, methodology and practical process. Gen AI as an evolving platform has the potential to create a design to production productivity shift that industry and academic groups have long predicted. Designing will remain creative and inventive, individualistic or team based and using what we have termed an AI design assistant, AIDA.

Keywords: Product design, engineering design, artificial intelligence (AI), 3D CAD, human computer interaction (HCI), design automation, large language models (LLMs), generative design, machine language (ML)

1 INTRODUCTION
Since the arrival of Chat GPT and the development of Gen AI in creative design there has been a proliferation of new businesses, exploring new services and ways of working to advance the design process such as Generative Biomimicry, Topology Optimisation, 3D Image creation and Text to 3D CAD. Designers using or experimenting with Gen AI programs are discovering services and features which can produce convincing design options in seconds. With an extensive research background Cross N [1] studied both human and computer in relation to design ontology; and he suggested that AI and computational processes can lead to insight about human cognition. And so, we can expect many unexpected opportunities in linking (LLMs), Gen AI with 3D CAD to help explore conceptual territory and give designers the working tools to think differently.
This study concerns itself with recommending the creation or evolution of an AI Design Assistant (AIDA) to increase the performance of designers and engineers. As with any new technology this will come with its learning and training issues, although enthusiastic users and early adopters should play a positive role in development, testing and feedback. It is not always about speed, and designers know the importance of standing back and having some thinking time to apply their creative knowledge and avoid problematic consequences, this will not be the job of our new AI design tools. Being able to create well considered sustainable products will rely on the skills of our best designers, and these new AI tools will permit them to design far more quickly than they can at present. In the field of product design, we are experiencing rapid progress with AI led generative software because it offers novel and efficient ways of designing. There may be a broader impact on design jobs, but just as likely designers will become more productive and some of the time intensive work becomes easier to do with the help of AIDA, freeing time to work on other projects.

2 LITERATURE REVIEW

Since the introduction of Chat GTP using Gen AI capability, the potential for getting questions or detailed research options has proliferated, albeit with some known limitations, nevertheless a technological revolution is occurring, and the design process will be profoundly affected. Developers and designers are launching new products which provide clues as to these changes such as (LLMs) to create both 2D and 3D representations of reality. A team from Autodesk [2] integrated DALL-E a plugin that that generates 2D image inspiration for 3D design and allows users to construct text and image prompts based on what they are modelling. A team from Autodesk and academia [3] have demonstrated that natural language can be used to generate and edit 3D shapes and they have discovered an approach which can produce high-fidelity models. This approach can help augment 3D design workflows rather than replace them. A team from France [4] propose to integrate design rules and CAD software into a data model which would help engineering teams by allowing access to information specific to their professional domain which is generally hidden in unstructured technical manuals using a context aware cognitive design assistant. In a review of Deep Generative Models in engineering design [5], it is proposed that the role of Automated Design Synthesis has the potential to revolutionise the modern engineering design process using Machine Learning and Deep Generative Models relating to a knowledge resource encoded in the vast expanse of existing designs.

Yang Q et al. [6] explain how Human Computer Interaction (HCI) designers struggle to envision and prototype AI systems because the scale and complexity of the project algorithms makes it virtually impossible to predict all outcomes and HCI designers use both complex, resource-intensive technologies and simple inexpensive artifacts such as paper prototypes and Wizard of Oz systems to help visualise and explain their concepts. De-Peuter S et al. [7], Propose AI assisted design (AIAD) a framework for developing collaborative assistance for design problems is defined 'AI should aim to cooperate, not automate, by supporting and leveraging the creativity and problem-solving capabilities of designers'.

Generative design is popular in Product and Engineering design and using the chair as an exemplar [8], the authors question the relationship between man and machine finding that the designers' professional experience to be the most important factor in a good outcome and that design plugins are currently insufficient to design a whole product. A team from Strathclyde University [9] have reviewed the field of AI in Product Design and Smart Manufacturing and note how AI is impacting on the design process and how better historical data will improve designs, reconstruction times and development of material selection. Wang X et al (2023) [10] highlight the potential for human machine collaboration, knowledge management, design innovation and engineering skills education. In [11], Brem A et al. discuss the immense transformative potential of AI and specifically how this is transforming innovation. They discuss the potential of AI in new product development at the early stages of creating novel and innovative designs using images or audio data. In [12], a design process using 3D Generative design is explored conceptually so the human designer can iterate and design faster.

The examples in Figure 1 provides a broad selection of what is significant and completed recently. It should be noted that the designer would remain in control of the development of the final product by evolving the organic potential of existing generative and topological software. Examples in the field of generative design usually involve single-part products, using a single production technology such as injection moulding or 3D printing.

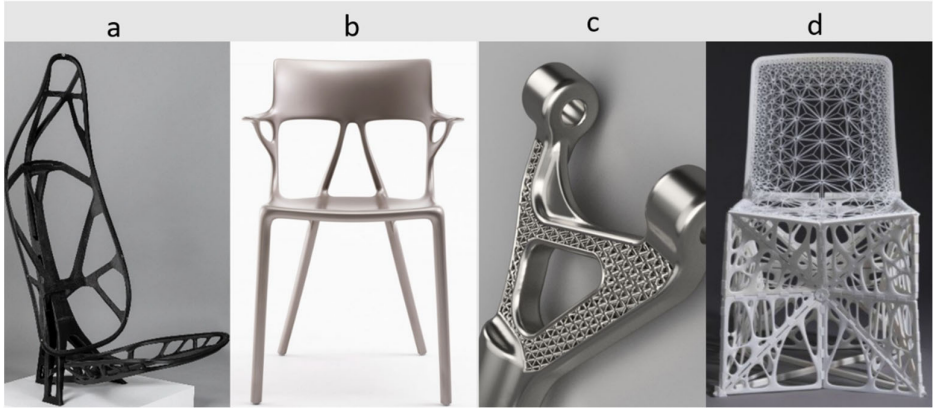

Figure 1. Generative Design Examples

In Figure 1a adjustable automotive car seat, Toyota wanted to simplify the complexity of the car seat and make the seat frame thinner, lighter and more sustainable. They worked with Autodesk, and they would not have imagined that it could be improved so significantly other than using the generative design process. Moreover, Figure 1b the Phillipe Stark AI chair was developed with Kartell & Autodesk using a generative process and the minimum amount of material which the designer described as being 'better than anything he could have done', perhaps this is indicative of some unexpected or future potential.
Additionally, Figure 1c, 3D metal printed brackets developed by Autodesk for the aerospace market using generative design and using topology optimization, which involves changing the internal structure of a solid to make it lighter in this case with a cellular latticework providing it with far more strength.
In Figure 1d The Patrick Jouin folding chair was created using Dassault systems 3D Experience software and he realised organic processes using machine algorithms. The platform was created to make it easier to achieve 3D printed products and the chair was presented at Milan Design Week.

3 RESEARCH THINKING

This work reflects our interest in getting the design process to be easier and more efficient as an evolved alternative to industry standard manual 3D software and encourage Gen AI as a means of efficiently creating 3D design concepts which are co-evolved by human and machine, with decision making firmly in the control of the designer.
AIDA will inevitably become easier and familiar to the designer and 3D CAD modelling will become quicker and more efficient. The quality of design thinking and experience remains just as crucial as it is now, with experienced designers exercising judgement and vision achieving the most productive outcome. Any design process which integrates CAD and automated AI process can still fail on a commercial level, so it will require intervention stages for humans to guide or re-direct the process.

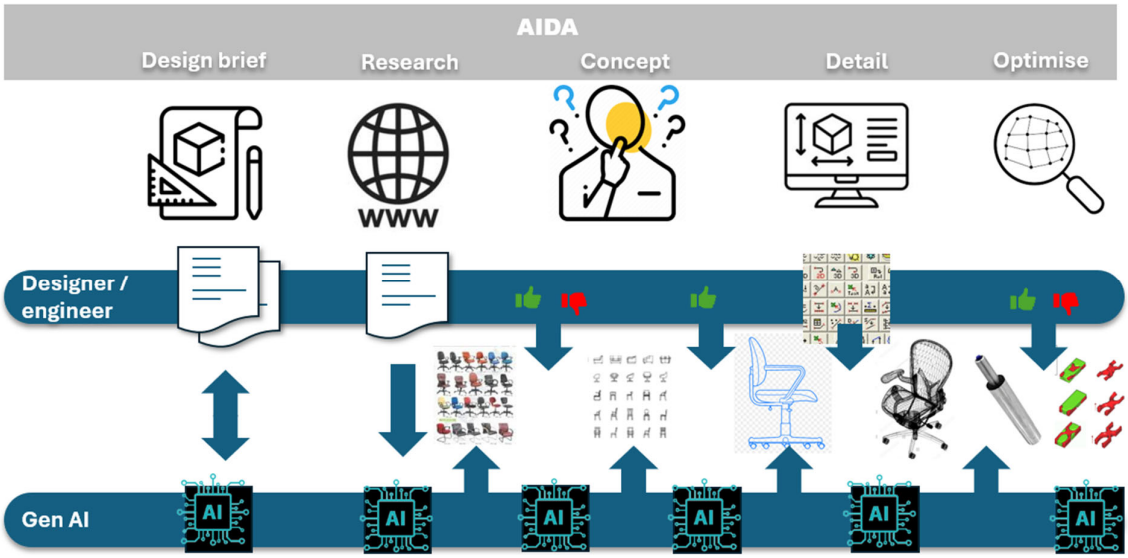

Figure 2. Artificial intelligence Design Assistant (AIDA)

The interface for designer interaction will vary through the stages of the design process; early brief and specification stages are most readily served by current text based LLMs, tools for subsequent stages will be developed with visual select / reject then CAD-like interfaces. The following stages explain how this might work on a practical level and we can deal with the how in future research:

- Stage 1. The designer starts with writing a brief entered into text based LLMs such as Chat GPT and it provides a detailed document with potential options so all aspects such as product descriptions, technical requirements and broad categories are included for consideration; the brief is evolved and changed as required.

- Stage 2. A request for market research information can be made to comprehensively identify what exists in a field and using a select/reject visual prompt, iterate towards the preferred design direction such as an office chair design and the designer creates a broad market presentation for design manager or client, listing market and category types with bulleted style, feature and material observations.
- Stage 3. Edit and reduce the large number AI options to a recommended few to pursue and develop. At this point the designer runs a 3D model generative concept creator while sketching and thinking about personal ideas. The AI concept generator options are narrowed by select/reject, but the designer has the option to add in a concept which is described in text and adjusted numerically via the prompt screen and added to the AI options. The designer then adjusts some of the other AI concepts in the prompt screen again with text and numbers until the client presentation is accepted.
- Stage 4. A preferred design starts the detailed design stage, and the designer starts to work on a 3D model adjusting forms in text and numerical prompt stages. Additionally access to 3D component databases with text and numerical prompt changes and full components are added to the model. AI is then asked to create 3 generative options via the Prompt screen and the designer decides one of these AI options is better than the original but once again they make plenty of adjustments in the Prompt screen until a client presentation is complete.
- Stage 5. The Optimise stage has the designer doing far more traditional 3D CAD adjustments but the Prompt screen is still available for text and numerical adjustment as is the option for AI to create 3 or more further optimised generative options.

As mentioned above, several research initiatives in industry and academia have been working in LLMs to generate 2D & 3D CAD but not a destination point on how Gen AI can help make designing easier throughout the complete process. We have observed profound change in the design industry and aim to define a realisable and adaptable version of how product designers can design differently and arguably better.

3.1 Research practical

To validate the proposed approach AIDA, four prompts were written to design four different chairs without using traditional 3D CAD software such as Solidworks or Autodesk Fusion 360. The aim is to prove what could be done in both text to 3D image creation (as seen in Figure 3) and text to 3D CAD (as seen in Figure 4). To do so we used online service providers to test our hypothesis that designing of a product will eventually become a co-creation process for designers and engineers with an AI design assistant such as AIDA.

Technology to explore the potential of the AIDA concept was available via internet service providers of AI to image & AI to 3D CAD, as a service sector it is in its infancy, but is nonetheless using very clever LLMs technology indicating a direction of travel when considering how design tools will change.

In a search for an AI-3D model generator Fotor.com was utilised with its potential for design concept creation of a chair. It proved useful as a research tool for this project and can help relieve aspects of design fixation, create alternative concepts and high-quality photorealistic presentations. With its Prompt text commands we requested, Plywood dining chair & Plywood dining chair with arms. The complete learning and practice process with Fotor.com including creating 4 designs was two hours. A variety of results were achieved, symmetric and asymmetric and a second design option appeared in two of the image generator attempts.

Figure 3. Text to 3D image

Then the potential of text to 3D CAD model was explored via Zoo.dev to create chair options from a text and prompt window and download step file products which was relatively easily. The images in Figure 4 may seem basic but this is a new technology allowing the creation of a 3D CAD model and downloadable file solely from text input. We requested: Chair; Dining chair; Dining chair with arms and a height adjustable office chair. The LLMs algorithm conducted a search and loaded some basic geometric forms to represent the product requested. We don't know the algorithm functional routine, but it seems to search for product types online then mimic objects by reducing them to basic 3D block forms. It works best for single item objects but showed potential for multiple component products too. Once this technology can access a much bigger dataset then it should start to return some more useable options for design development. This is an Alpha software development version, though it helped us to envision an integrated design tool to link early conceptual work to detailed CAD development using primarily a text prompt.

Figure 4. Text to 3D CAD

4 DISCUSSIONS

We gained a positive impression of text based (LLMs) & prompt screens to continuously tune the design brief and conduct research. We see development potential for using Text to 3D CAD code blended with traditional 3D CAD so that Gen AI 3D models can be produced at concept, concept development and product detailing stage. This allows generative design options to be explored at the concept and detailed design stage in fact all stages of the design process, concepts will be efficient to prepare and present, and later used for generative design options or modified and detailed at any stage in the design process. This means we lose the need to fix designs at 3D CAD stage and designers have a single tool from concept to production. This is the basis of a long-term proposal to create a single design platform start to finish AIDA without any limitations on concept and product generation.

The design process using this suggested AIDA allows text, graphical menu selection or numerical adjustment to 3D objects via a prompt screen, a relatively blunt tool at concept stage which can also function as a 3D parametric CAD tool when required. At any stage it can produce generative options such as design concepts, although it uniquely works also at the product detailing stage. Options are usually narrowing towards the production stage, but dramatic change can sometimes be required because an unexpected change can arrive later than planned. AIDA help would mean a significant change is less stressful and costly. Generative design solutions in this proposal relate to design morphology and topology. Biomimicry is currently a very popular in design led production and particularly in 3D printing, however fashions and needs change so we will require an integrated design method of achieving more complex and better 3D products.

5 OPEN RESEARCH QUESTIONS FOR AIDA

Product designers are witnessing an increase of activity in AI related projects which require evaluation and good questions before we decide what help is needed to assist in the practice of designing. Our proposal for an AIDA approach will eventually integrate with industry CAD/CAM products with seamless functionality and therefore, the following questions require further research before progress can be made:

- When can we access the right quality of 3D object and component datasets?
- What type of algorithms and expertise are required to implement AIDA?
- How do we make AIDA intuitive and efficient to use?

- How do we implement a user-friendly prompt menu?
- How do we achieve incremental (imprecise) concept change then fine tuning (precise) product development within AIDA?
- Can we integrate Morphology & Topology with aesthetic options – not just biomimicry?
- How are generative and parametric characteristics combined?

The design process using an AIDA will not change design stages or decision making it just means that an AIDA will do some of the heavy lifting by answering research questions and providing computer generated design options, both earlier and later in the design process than previously possible and it requires experienced designers to achieve a high-quality outcome. There are no AI shortcuts for design expertise, just time saving efficiency for those that know how to use this new technology. Additionally, the next generation software needs to facilitate the design of complex multi-component products which is not yet a practical service offering of Gen AI product development.

6 CONCLUSIONS

The integration of heuristic shortcuts to Machine Learning and the advent of Large Language Models like Chat GPT, highlights the potential of Gen AI in revolutionising the design process. This paper focuses on how AI, particularly Gen AI and 3D CAD integrated software, can optimise designers' efficiency from concept to production without compromising the quality of design thinking. Keeping a multiple component product well managed is of great interest to designers who work with a multitude of 3D CAD software providers with numerous optional bolt-on products. We believe that our AIDA proposal helps define a destination for a co-creation tool which lets humans do the creative thinking and AI the big processing tasks. We recognise this will require vast development input and ultimately some very clever and intuitive prompting tools. The evolving nature of Gen AI holds the promise of a significant productivity shift in design to production, offering exciting prospects for both industry and academia.

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